UNCLASSIFIED

AD NUMBER

AD012618

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution; No Foreign

AUTHORITY

afal ltr, 17 aug 79

THIS PAGE IS UNCLASSIFIED

TI-855

6/22/53

WADC TECHNICAL REPORT 52-229, Part 1

AD-12618

THE INFLUENCE OF SURROUND ON TRACKING PERFORMANCE

Part 1. Tracking on Combined Pursuit and Compensatory One-Dimensional Tasks With and Without a Structured Surround

JOHN W. SENDERS
AERO MEDICAL LABORATORY

FEBRUARY 1953

WRIGHT AIR DEVELOPMENT CENTER

20010501005

AF-WP-(B)-O-19 JUN 53 200

NOTICES

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

The information furnished herewith is made available for study upon the understanding that the Government's proprietary interests in and relating thereto shall not be impaired. It is desired that the Judge Advocate (WCJ), Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, be promptly notified of any apparent conflict between the Government's proprietary interests and those of others.

WADC TECHNICAL REPORT 52-229, Part 1

THE INFLUENCE OF SURROUND ON TRACKING PERFORMANCE

Part 1. Tracking on Combined Pursuit and Compensatory One-Dimensional Tasks With and Without a Structured Surround

John W. Senders
Aero Medical Laboratory

February 1953

RDO No. 694-39

Wright Air Development Center
Air Research and Development Command
United States Air Force
Wright-Patterson Air Force Base, Ohio

FOREWORD

This report was prepared by the Psychology Branch of the Aero Medical Laboratory, Directorate of Research, Wright Air Development Center, under a project identified by Research and Development Order No. 694-39, "Servo Analysis of Human Control Systems," with John W. Senders acting as Project Engineer.

The collection of the data was performed by Antioch College on Contract AF 18(600)-50 under the direction of Dr. V. L. Senders.

ABSTRACT

Four groups of subjects performed a series of tracking tasks on two different target courses and under two conditions of surround illumination. The tasks were varied from pure compensatory to pure pursuit (following) tracking. In general, performance was superior with either surround illumination with a 50 or higher percent of pursuit component. However, the interactions between target course rates, surround illumination, and percent pursuit component in the task are large and complex.

This is the first of a series of studies on the same subject.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDING GENERAL:

Robert H. Blount

ROBERT H. BLOUNT
Colonel, USAF (MC)
Chief, Aero Medical Laboratory
Directorate of Research

TABLE OF CONTENTS

ILLUSTRATIONS

TABLES

I. INTRODUCTION

In a prior report (WADC TR 52-39) it was shown that tracking performance on a one-dimensional visual tracking task improves as the pursuit component is increased and the compensatory component is reduced. These terms are here defined as follows:

A task having only a compensatory component is one in which an operator is presented with a display consisting of an indicator and a zero reference point, and is required to maintain the indicator on the reference point by compensating for the movements of the indicator imposed upon it by outside influences. A motorist, trying to maintain a constant speed by keeping his speedometer needle always on 50, or a radar operator maintaining a target pip on the center of the screen, are both engaged in compensatory tracking. A perfect performance in a compensatory tracking task would result in a situation of no movement, since the target, or zero reference point, would never move, and if tracking were perfect the follower or pip or needle would never move off the reference point.

A task having only a pursuit component is one in which an operator is presented with a display consisting of two indicators, called, for convenience, the target and the follower. The target is caused to move by outside influences and the operator controls the follower in such a way as to keep it superimposed on the target. A gunner, following a moving airplane with the sights of a flexible gun on a fixed platform, is engaged in pursuit tracking. Perfect pursuit tracking of a continuously moving target would result in continuous movement, since as the target moves, the follower would reproduce this movement perfectly. Past research (5) has demonstrated that as the percent of pursuit component in a tracking task is increased from 0% to 100%, time-on-target scores also improve; the greatest improvement takes place when the percent of pursuit component was increased from zero to 50%. A possible reason for this improvement is that with no pursuit component (compensatory tracking) the only information available to the operator is that provided by displacement; as more pursuit component is added, information about the direction, rate, and acceleration of target motion becomes increasingly available. The experiment reported here was designed to test the hypothesis that the availability of such information, in general, adds to improved tracking performance.

This hypothesis leads to the specific prediction that the greater the proportion of perceptible (i.e. above threshold) rates in a target course the higher will be the time on target. An increase in the proportion of perceptible rates may be achieved in two ways:

1. The proportion of high rates in the target course itself may be increased. This is accomplished either (a) by increasing the amount of pursuit component in the task or (b) by increasing, for any given amount of pursuit

component, the proportion of high rates in the target course (in this case by altering the cam.)

2. The threshold of rate perception may be decreased. This can be accomplished by changing from a condition which presents the observer no frame of reference to one in which the surround or frame of reference is clearly visible. Aubert (1) found rate thresholds of the order of 1 to 2 minutes of arc per second when the stationary parts of the apparatus were clearly visible; this threshold was elevated by a factor of approximately ten when a fixed visible surround was eliminated. The order of magnitude of these values is confirmed by later investigators (2, 3).*

II. APPARATUS AND PROCEDURE

Apparatus: The apparatus used was the same as that described in a prior report (5) and is shown in Figure 1. The display surface was the face of a cathode ray oscilloscope. On this surface were presented a spot of light of the minimum size obtainable, approximately 1 millimeter, and a circle approximately 7 millimeters in diameter with a rim thickness equal to the diameter of the spot. The dot was controlled only by the problem generator, and the circle both by the problem generator and by the subject's control. The proportions of the two factors controlling the circle motion were variable, and the dot motion was varied concomitantly in order that the corrective motion required for each segment of the problem cam would be constant for any setting of the proportioning control. For an ideal performance, therefore, the required motor output of the subject was the same for all experimental conditions. Time-on-target scores were taken when the spot was within the circle.

---

* An interesting phenomenal counterpart of this change, noted in the present experiment, is discussed by Koffka: (4)

"Supposing the field is homogeneously dark and contains only two light objects, one of which is in objective motion while the other is at rest. Then, if the velocity of motion is not great, the chief determining factor (of perception of motion) will be the relative displacement of the two objects. This, according to our theory, must lead to perceived motion, but our theory does not permit us to deduce which of these objects will be the carrier of the motion, as long as their relative displacement and no other factor becomes effective."

and further

"...if one of the two field objects has the function of framework for the other, then it will be seen at rest and the other as moving, no matter which of the two moves in reality. If on the other hand the two objects are both things, then under symmetrical conditions (fixation between them or freely wandering regard), they should both move in opposite directions."

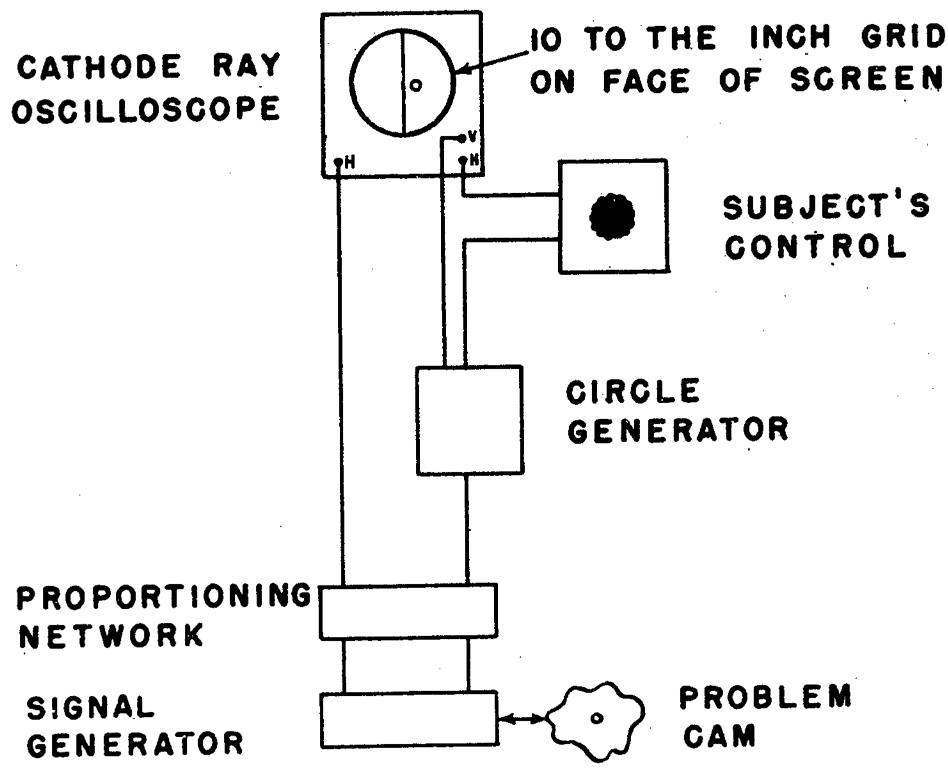

FIGURE I: BLOCK DIAGRAM OF APPARATUS

Procedure: The apparatus was allowed to warm up for one hour prior to the actual testing of the subjects. The warm-up period eliminated virtually all drift from the amplifiers during experimentation. Immediately before running each subject, the equipment was checked to insure that the scoring area was correct in width and centering.

The subject was seated before the display so as to place the screen of the cathode ray tube at eye level, approximately 14 inches away from the subject's eyes. To the right of the display (left for left-handed subjects) was an arm rest and the subject's control knob. Subjects were given the following instructions:

"Each trial will be one minute long. Your task is to keep the circle over the dot by moving this knob appropriately. There will be five one-minute trials and then a two-minute rest. After each trial place the circle over the dot if it is not already there. Your task will be the same for each trial, although the nature of the trials may vary." (i.e. The tasks differed from each other in the amount of pursuit component each contained.)

The subject was allowed a two-minute rest between successive sets of five trials, and a five minute rest between the third and fourth sets. During these rest periods the experimenter again checked the accuracy of the scoring apparatus and made any necessary adjustments. This procedure was repeated for two successive days. As a preliminary check on the setting of the apparatus, conditions were restored to those obtaining in the first experiment (low rate, full surround) and a series of trials given to five subjects. The results were substantially the same as before, and indicated that no major characteristics of the task had changed.

Experimental variables: The independent variable in all sessions was the percent of pursuit component in the task. Five conditions, defined by the motions of spot and circle induced by the problem cam, were tested:

1. 0% pursuit. (100% compensatory): The circle moved and the subject tried to return it promptly and correctly to the (stationary) spot, which provided the zero reference point.

2. 25% pursuit. The ratio of spot movement to circle movement was 1:3. That is, if the spot moved one degree to the left, the circle moved three degrees to the right.

3. 50% pursuit. The ratio of spot movement to circle movement was 1:1. If the spot moved two degrees to the left, the circle moved two degrees to the right.

4. 75% pursuit. The ratio of spot to circle movement was 3:1. If the spot moved three degrees to the left, the circle moved one degree to the right.

5. 100% pursuit. Only the spot was moved by the cam, the circle remaining stationary unless moved by the subject.

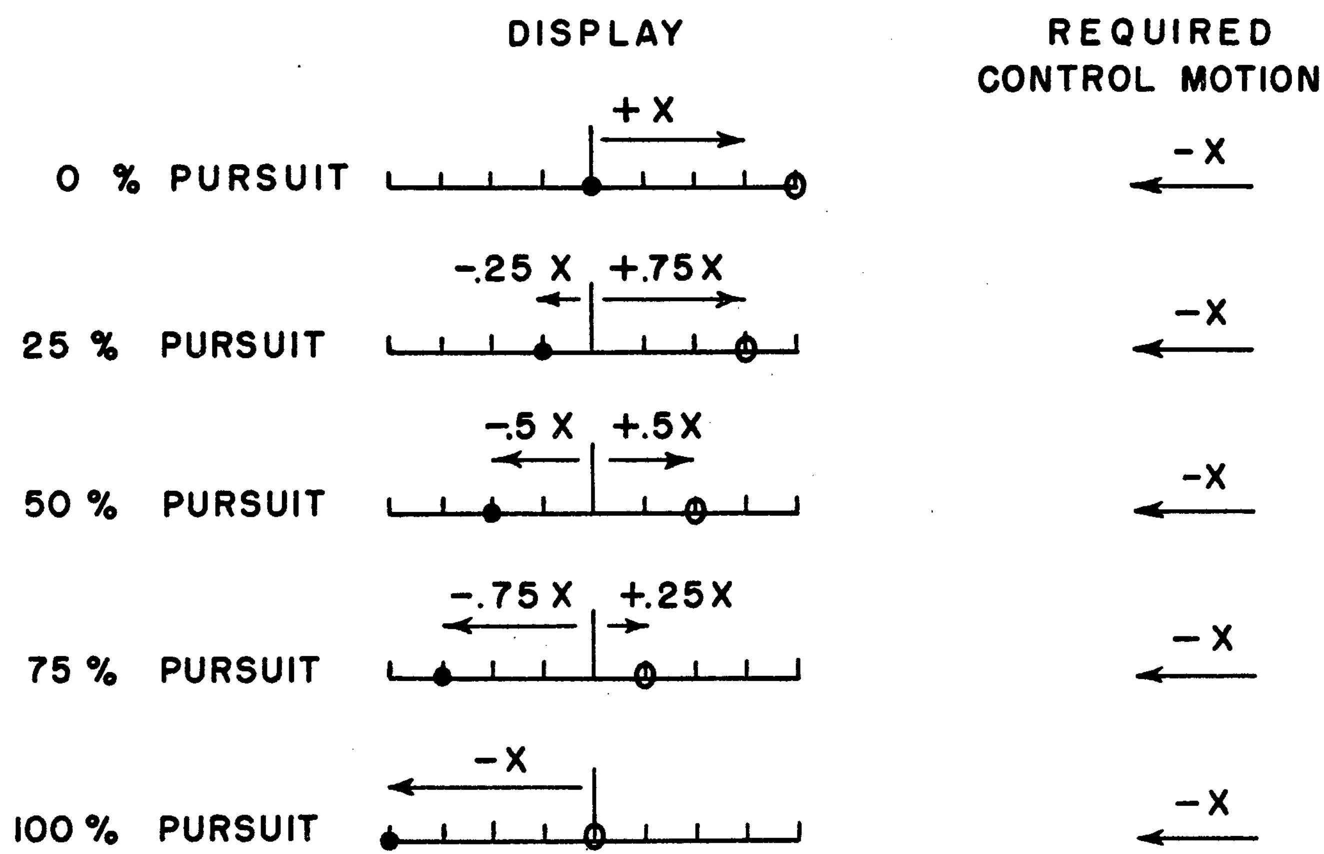

FIGURE 2: CONTROL MOTION AND DISPLAY VARIATIONS FOR A CONSTANT INPUT UNDER VARIOUS CONDITIONS.

These conditions were achieved by dividing the cam output between the target spot and the follower. Only the circle was under the subject's control, and in all conditions the control motion required to maintain the circle over the spot was identical, both in direction and in amount. Figure 2 shows in schematic fashion the display changes and the required control movement for a given slope of the cam profile.

The order of presentation of the various conditions was such as to counterbalance the effects of order.

Parameters: Two parameters were introduced into the experimental design. Both were ways of changing the proportion of perceptible rates in the target course.

1. Distributions of rates in the target course. Two problem cams were used. One, which was used in the previous experiment, provided a preponderance of low rates, and the other provided higher rates. The high rate cam included rates which were above threshold, even when target motion had been reduced by 75% by using only 25% pursuit component in the task, and when thresholds were simultaneously raised by the use of the no-surround conditions.

2. Surround. Two surround conditions were used. The first was identical with that of the previous study, and is referred to for convenience as the "light condition." In this condition, the whole face of the cathode ray tube, a grid superimposed on it, pilot light, the oscilloscope itself, and parts of the experimental room were visible to the subject. In the "dark" or no-surround condition, all illumination from the tube was reduced to zero (i.e. a value below the observers' thresholds), pilot lights were masked, and all ambient illumination was eliminated. The observer could see only the target and the follower. The purpose of this reduction of surround was, of course, to raise the observers' rate thresholds.

Five subjects were used under each of four conditions: low-rate cam and light condition, low-rate cam and dark condition, high-rate cam and light-condition, and high-rate cam and dark condition.

III. RESULTS

The means for each subject on each day and for the groups are listed in Tables I and II, and are shown graphically in Figure 3.

Effect of percent of pursuit component: In general it may be said that an increase in the percent of pursuit component in the tracking task improves performance, as measured by time-on-target scores. This finding is in accord with that of the previous study. (4)

Effect of target rates: Under both surround conditions, an increase in the proportion of high rates in the cam results in improved tracking perfor-

TABLE 1

Low Rate Target Course

Day	Subject	Light Cond.	Compen.	.25 Pur.	.50 Pur.	.75 Pur.	Pursuit
	F.L.		22.28	22.69	23.41	21.74	25.56
	R.B.		22.77	22.29	27.41	29.18	30.86
1	Z.J	Dark	14.55	17.47	18.09	18.36	19.69
	R.S.		13.94	16.61	17.76	20.40	19.74
	H.W.		21.87	24.68	27.18	30.78	28.40
	F.L.		24.15	25.05	26.16	24.66	23.21
	R.B.		25.61	26.48	29.24	28.32	25.98
2	Z.J.	Dark	15.64	14.71	14.59	19.94	19.54
	R.S.		12.48	13.01	16.41	18.82	18.99
	H.W.		27.66	28.12	27.93	28.56	27.15
Two day mean			20.10	21.11	22.82	24.08	23.91
	E.L.		20.36	21.23	26.76	29.36	26.24
	J.W.		16.27	20.08	22.33	25.82	23.50
1	D.W.	Light	19.50	21.71	23.73	25.15	25.23
	N.H.		24.06	23.91	24.06	26.80	28.84
	F.J.		20.56	25.65	25.03	25.49	24.11
	E.L.		21.84	27.44	27.80	28.33	26.31
	J.W.		16.41	17.47	24.13	23.57	19.54
2	D.W.	Light	23.36	26.33	28.52	27.89	26.22
	N.H.		23.85	26.62	27.49	30.62	32.48
	F.J.		20.38	23.21	25.52	25.30	23.22
Two day mean			20.66	23.37	25.54	26.73	25.57

Time on Target Scores for Each Subject
on the Low Rate Target Course

TABLE 2

High Rate Target Course

Day	Subject	Light Cond.	Compen.	.25 Pur.	.50 Pur.	.75 Pur.	Pursuit
	J.C.		16.14	19.31	22.18	22.08	23.91
	J.K.		17.77	19.08	21.79	25.76	24.47
1	M.L.	Dark	16.42	18.10	21.19	22.70	23.24
	J.B.		14.01	15.71	18.52	20.00	19.22
	H.W.2		19.26	23.32	26.80	26.97	28.18
	J.C.		17.02	22.96	24.61	26.48	27.04
	J.K.		23.73	25.13	29.55	30.63	28.32
2	M.L.	Dark	15.06	19.07	20.24	24.15	22.48
	J.B.		11.07	12.66	15.42	17.81	16.63
	H.W.2		20.78	23.59	26.38	27.53	27.82
Two day mean			17.13	19.89	22.67	24.41	24.13
	J.M.		14.80	23.40	27.47	27.78	28.65
	M.W.		16.53	19.53	25.38	24.72	26.33
1	A.B.	Light	13.73	20.69	26.07	24.40	24.94
	A.K.		17.50	22.23	23.76	24.98	25.67
	C.C.		19.40	25.15	27.55	26.96	27.22
	J.M.		21.39	24.98	26.20	29.17	27.29
	M.W.		17.43	18.35	25.78	28.18	27.75
2	A.B.	Light	16.56	24.67	26.87	26.98	28.17
	A.K.		19.40	23.73	24.22	25.69	25.51
	C.C.		22.43	26.39	29.28	31.57	25.72
Two day mean			17.92	22.91	26.26	27.04	26.73

Time on Target Scores for Each Subject
on the High Rate Target Course

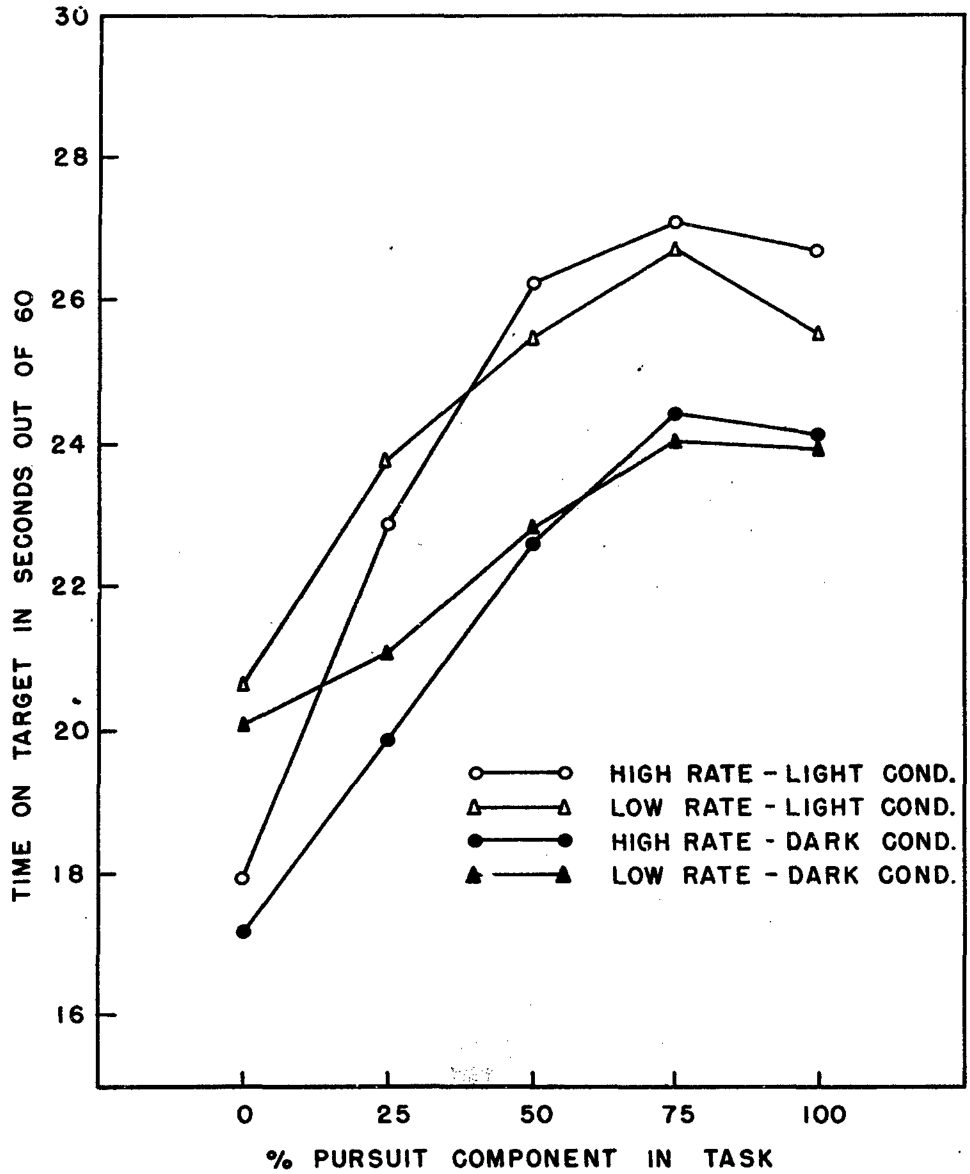

FIGURE 3

MEAN TIME ON TARGETS SCORES FOR THE FOUR GROUPS

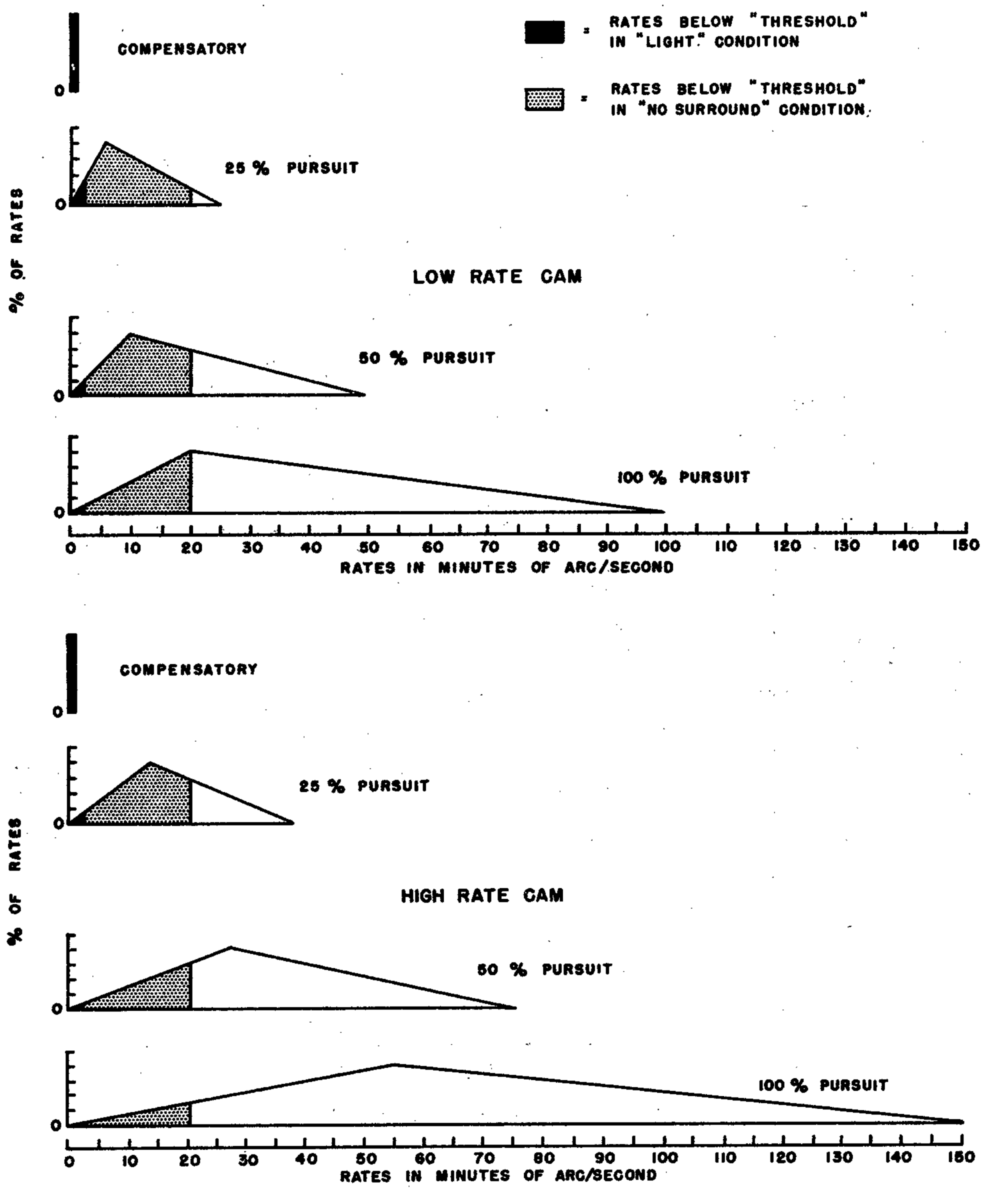

FIGURE 4: APPROXIMATE DISTRIBUTIONS OF VISUAL RATES PRESENTED BY THE TARGET CAMS

mance on the 75% and 100% pursuit tasks and lowered performance on the compensatory and 25% pursuit tasks. With the illuminated surround, performance with the high rate cam is better at the 50% pursuit task. With no surround it is poorer if at all different. It will be remembered that with a compensatory task no rate information, and with the 25% pursuit task relatively little rate information, is available to the subject on either cam. Furthermore, it seems likely that the motor task involved in tracking a high rate cam is more difficult than that involved in tracking a low rate cam and that only for compensatory and 25% pursuit tasks would this difference appear in isolation.

Effect of surround: With both cams, performance is markedly superior under the light condition; furthermore, the superiority increases with an increase in the percent of pursuit component in the task up to and including the 50% pursuit point. Of particular interest is the fact that under the dark condition there is virtually no improvement for the low rate cam between compensatory and 25% pursuit (1 sec), while under the light condition, there is a marked improvement. With the high rate cam, performance is better under the light condition and the rate of improvement between compensatory and 25% is greater than it is under the dark condition. However, there is an appreciable increase in performance in the dark condition.

Interactions: That none of the above components contributes to performance in a simple way is clearly shown in Figure 3. The effect of high rates, for example, is to depress performance in compensatory tracking but elevate it in pursuit tracking. For the light condition, the high and low rate functions cross between 25% and 50% pursuit, while for the dark condition they cross between 50% and 75% pursuit. All of these results are in accord with the hypothesis that, other things being equal, tracking performance improves as a function of the proportion of above-threshold rates in the target course.

IV. DISCUSSION

An increase in the proportion of above-threshold rates in the target course can be achieved by changing the stimulus by (a) including a greater proportion of high rates on the cam and (b) making more of these rates available by increasing the amount of pursuit component; or by lowering the observer's threshold by adding a visible surround or frame of reference. The way in which each of these conditions affected the rate distribution is shown in Figure 4. In the upper half of this figure, are the distributions of rates for the low rate cam, as modified by the proportion of pursuit component in the task. In the lower half the corresponding distributions are drawn for the high-rate cam. Rates below the threshold of rate perception for the full-surround condition, as obtained by Aubert, are shown as solid. Those below the threshold for the no-surround condition are shown as cross-hatched. Thus in each distribution, the light area represents rates which are above threshold for the no-surround condition; the light area plus the cross-hatched area represents rates which are above threshold for both surround conditions. Other things being equal, the greater the light, or light-plus-cross-hatched, area, the higher should be the time-on-target scores.

One factor which keeps other things from being equal is the difference in required motor performance for high and low rate cams. We may suspect that, when perceptual factors are equated, the higher rates of motor performance required by the high rate cam may have a deleterious effect on performance.

These distributions would lead us to expect that performance would always be poorest on a compensatory task; furthermore, compensatory tracking should be worse with a high than with a low rate cam. Increasing the pursuit component would be expected to lead to improvement in performance if the threshold is low enough or the rates high enough for an addition of pursuit component to lead to the addition of a significant proportion of perceptible rates. Thus on the low rate cam under the dark condition, relatively little improvement would be expected as a result of increasing the pursuit component; such improvement would, however, be expected either with high rates or a full surround.

All of these expectations are fully confirmed, and the data lend considerable support to the hypothesis that tracking performance is a direct function of the proportion of above-threshold rates in the target course.

V. CONCLUSION

From these results one might confidently predict that reducing the size of a visual tracking display would decrease performance on pursuit tracking if the operator is required to track a continuously moving target, and this reduction in performance would be due not only to the reduced apparent size of the position errors but also to the reduced rates of motion apparent to the operator. Further, a reduction in the illumination of the surround to near-or-below-threshold values would also reduce tracking accuracy by making less of the rate information contained in the display actually available to the operator. However, for almost any condition of display size and surround illumination, pursuit tracking is superior to compensatory tracking for the type of display described above. Presumably, if the target input rates were so low as to be below the threshold for movement perception, then any arrangement of the display would correspond perceptually to compensatory tracking and performance would be more or less independent of surround illumination, and of the distinction between pursuit and compensatory displays.

BIBLIOGRAPHY

1. Aubert, H., Die Bewegungsemfindung. Arch. ges Physiol., 1886, 39, 347-370.

2. Brown, J. F., The thresholds for visual movement, Psychol. Forsch., 1931, 14, 249-268.

3. Graham, C. H., in: Handbook of Exp. Psych., Stevens (ed). Wiley, 1951, 895-897.

4. Koffka, K., Principles of gestalt psych., Harcourt, Brace, 1935, 282-283.

5. Senders, J. W. and Cruzen, M., Tracking performance on combined compensatory and pursuit tasks, WADC TR 52-39, February 1952.